Ocean Model Development for COAMPS

Paul Martin
Naval Research Laboratory
Stennis Space Center, MS 39529
phone: (228) 688-5447 fax: (228) 688-4759 email: martin@nrlssc.navy.mil
Award #: N0001498WX30328

LONG-TERM GOALS

Develop a coupled ocean-atmosphere prediction system that can be used for hindcasting and forecasting coastal environments. This system is referred to as the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS). The atmospheric component of this system was developed by the Atmospheric Dynamics and Prediction Branch of the Naval Research Laboratory (NRL) and is currently in use at NRL and at the Navy's Fleet Numerical Meteorology and Oceanography Center (FNMOC) (Hodur, 1997).

OBJECTIVES

The objectives of this project are to develop an ocean model that contains some of the best features of existing coastal ocean models and meets the Navy's needs for conducting simulations and predictions in littoral environments, and to fully couple that model with the atmospheric model within the current COAMPS program architecture.

APPROACH

COAMPS consists of coupled ocean and atmospheric models. Two ocean models have previously been used with COAMPS. The first was developed for use in deep water and does not incorporate variable bottom depth. The other is the Modular Ocean Model (MOM) developed by the Geophysical Fluid Dynamics Laboratory (GFDL) at Princeton. MOM has some limitations for coastal use, and the MOM code is not presently in a form that allows use of the full flexibility for which the COAMPS program architecture was designed.

For coastal applications, an ocean model is needed that can accommodate the wide range of environments and processes that can be encountered in coastal regions, including complex coastlines and bathymetry, tides and storm surge, river outflows and coastal runoff, and flooding and drying of low-lying coastal areas. The purpose of this project is to develop an ocean model to provide these capabilities. The ocean model being developed in this project is referred to as the Navy Coastal Ocean Model (NCOM).

Based on results from the Coastal Model Comparison study conducted by the NOMP Ocean Model Performance and Evaluation Project at NRL (Martin, et al., 1998), it was proposed that the ocean model to be developed for COAMPS consist of the following main elements: (a) the basic physics and numerics of the Princeton Ocean Model (POM), (b) the combined sigma/z-level vertical grid system used in NRL's Sigma/Z-level Model (SZM), (c) a program structure fully consistent with COAMPS. and (d) some additional capabilities and refinements.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **1998**	2. REPORT TYPE	3. DATES COVERED **00-00-1998 to 00-00-1998**
4. TITLE AND SUBTITLE **Ocean Model Development for COAMPS**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Research Laboratory,Stennis Space Center,MS,39529**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM002252.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**4**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

A combined sigma/z-level grid system provides some additional flexibility over a sigma coordinate system in setting up a vertical grid for a particular region. With the combined grid system, sigma coordinates are used down to a user-specified depth, and z-levels are used below. The z-level grid, which is generally more robust in regions of steep bottom slopes than sigma coordinates, can be applied at the depths below which steep bathymetry may cause difficulty with sigma coordinates. The combined grid system also allows comparisons to be made between sigma and z-level simulations to identify problems that may be occurring with either coordinate system.

COAMPS has a very specific code architecture that is mainly defined by two attributes: (1) model variables are passed via subroutine argument lists rather than by common blocks and (2) model array space is dynamically allocated at run time. The reason for these attributes is to allow the same model code to calculate different nested grids for both the atmospheric and ocean models within a single program, and to avoid having to recompile the program for different simulations with different grids. An ocean model being developed for use in COAMPS needs to be structured to be consistent with the COAMPS code architecture. Most existing ocean model codes are not structured in this way.

It was desired to include some additional capabilities in NCOM that are not currently available in POM. These include an explicit source term to simplify inclusion of river and runoff inflows, forcing by the local tidal potential and the surface atmospheric pressure gradient, and the choice of either the Mellor-Yamada Level 2.5 turbulence closure scheme as used in POM or the simpler and more efficient Mellor-Yamada Level 2 scheme.

Some additional features planned for NCOM that have not yet been developed include providing options for truncating (shaving) of the bottom grid cell on the z-level part of the grid to the bathymetry, for flooding and drying, and for using an advection scheme that upwinds at fronts to reduce noise caused by numerical overshooting of the advection terms.

WORK COMPLETED

A Fortran code for NCOM has been developed that is fully consistent with the COAMPS architecture, i.e., that includes dynamic allocation of array space, passes all model variables through subroutine argument lists, and provides for an arbitrary number of levels of grid nesting. The nesting routines currently allow one-way nesting with sigma coordinates for an arbitrary number of nests.

A significant amount of effort was expended in FY98 to parallelize NCOM. This work was undertaken in part because of the increasing number of computers becoming available that require code parallelization for high performance, and in part because of the availability of assistance in FY98 from the Common High Performance Computing Software Support Initiative (CHSSI) Program to help parallelize NCOM. The work required to parallelize NCOM for running on a single grid (without nesting) is about 90% completed.

In conjunction with NRL's Coastal Remote Sensing Project (CoRS), NCOM was used to conduct simulations of the outflow plume from Chesapeake Bay. These simulations included runs with

singly and doubly nested grids to provide increased grid resolution in the mouth of Chesapeake Bay.

RESULTS

A Fortran program for NCOM has been developed and tested. This code is described by the following features.

Model physics: primitive equation, incompressible, free surface, hydrostatic, Boussinesq, Laplacian horizontal diffusion, horizontal eddy coefficients calculated based on minimum value and a maximum grid-cell Reynolds number, option of Mellor-Yamada Level 2 or Level 2.5 vertical mixing scheme, explicit source term in all equations to simplify river and runoff inputs, and forcing included for local tidal potential and atmospheric surface pressure.

Model numerics: C-grid, leapfrog in time with Asselin filter to suppress timesplitting, 2nd-order, centered spacial finite differences, curvilinear horizontal grid, combined sigma/z-level vertical grid, implicit treatment of the free surface, implicit vertical mixing, capability of running with periodic boundaries in either or both directions, and seamless restart capability.

A general nesting scheme has been implemented in NCOM, which allows for an arbitrary number of levels of nesting. Because all the model variables are passed through subroutine argument lists, the same subroutines can be used to calculate different model grids within the same Fortran program. The model calculations are controlled by a "logic" subroutine that determines which ocean model grid and which particular calculation for that grid needs to be done next and sets a number of logical variables to control the succeeding calculations. This program arrangement for NCOM results in a flexible nesting procedure that has a fairly clean, simple coding structure.

The nesting procedure was tested by performing simulations of the outflow plume from Chesapeake Bay. Singly and doubly nested grids were used to provide increased grid resolution near the mouth of Chesapeake Bay. The nesting procedure was found to be easy to set up and use. The nested grids worked well, and the results from the simulations showed good qualitative agreement with observations.

Work was begun in FY98 to parallelize NCOM. Dr. Alan Wallcraft of NRL, who is funded by the CHSSI Program, helped in this effort and provided the parallelization expertise. NCOM has been parallelized using a "tiling" approach in which the model domain is horizontally divided into a number of equally-sized subregions or tiles, and each subregion is calculated on a separate processor. The NCOM code was modified so that calculations on a particular tile can accommodate tile boundaries that are either exterior boundaries, as they would be if the calculation on the processor were being done for the entire domain, or are interior boundaries that adjoin other tiles. Message passing between processors is handled using several methods. The parallelization is being made sufficiently general that NCOM should be able to be run in parallel on a variety of computers. The work required to parallelize NCOM for running on a single grid, i.e., without using nesting, is about 90% completed. The parallelization of the grid nesting procedure has not yet been addressed.

IMPACT/APPLICATIONS

The ocean and the atmosphere are strongly coupled in coastal regions, and a combined ocean-atmosphere modeling system is frequently the optimal means of hindcasting and forecasting coastal areas. COAMPS is being developed by NRL to provide a high-resolution, coupled ocean-atmosphere prediction capability.

The payoff from this ocean model development project will be a functional and flexible model for ocean prediction that can be run by itself or can be run fully integrated with an atmospheric model in COAMPS.

TRANSITIONS

NCOM has been used during FY98 by NRL's Coastal Remote Sensing (CoRS) Project to investigate the outflow plume from Chesapeake Bay. These simulations have used singly and doubly nested grids (with a maximum horizontal resolution of 200 m) to look at the behavior of the outflow plume near the mouth of Chesapeake Bay caused by wind and tidal forcing.

A project to develop a global version of NCOM for real-time simulation of the ocean circulation and temperature and salinity structure is starting in FY98. The model will initially be set up for 1/4 degree resolution, and will make use of assimilated surface elevation and temperature observations.

RELATED PROJECTS

NRL-Monterey is being funded by NOMP to assist in the development of NCOM and the installation of NCOM into COAMPS.

A joint project between NRL-Stennis and NRL-Monterey, entitled "Ocean Data Assimilation for COAMPS", is working to develop an ocean data assimilation system for COAMPS.

Dr. Alan Wallcraft of NRL, working under the CHSSI Program, has been helping to parallelize the NCOM code.

REFERENCES

Hodur, R. 1997: The Naval Research Laboratory Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS). *Mon. Wea. Rev*., *125*, 1414-1430.

Martin, P. J., G. Peggion, and K. J. Yip, 1998: A Comparison of Several Coastal Ocean Models. NRL Report, in press. Naval Research Laboratory, Stennis Space Center, MS 39529.

PUBLICATIONS

Martin, P. J., 1998: A description of the Navy Coastal Ocean Model (NCOM) Version 1.0. NRL Report, in press, 40 pp.